SCOTTISH CENTRE: CHAIRMAN'S ADDRESS

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"THE NOMENCLATURE OF THE FUNDAMENTAL CONCEPTS OF ELECTRICAL ENGINEERING."

(*Address delivered at* GLASGOW, *20th October*, 1931.)

"The importance of nomenclature was recognized in the earliest times. One of the first duties that devolved upon Adam on his installation as gardener and keeper of the zoological collection was the naming of the beasts."—OLIVER HEAVISIDE.*

In reading over the paper in the *Philosophical Transactions of the Royal Society* for November 1831 in which Faraday describes in minute detail the experimental discovery and the investigation of electromagnetic induction, I was struck by the entire absence, and indeed the impossibility at that date, of any exact measurement and by the absence of such words as "resistance" and "electromotive force;" and it occurred to me that the history of the development of the conceptions and terms which are now used in electrical engineering would form a very suitable subject for this address.

A large body of interconnected concepts has grown up, and names have been given to these concepts. Their accurate measurement and statement necessitated the adoption of a system of interconnected units, and unfortunately led to the introduction of several systems of units. Names have been given to many of these units. The development of the subject has led to the continual emergence of new concepts, leading to the introduction of new names to describe them and of new units by which to express them. The existence of several systems of units has led to the development of other systems alleged to have all, or most of, the merits of all the older systems and few of their defects, and the supporters of each new system advocate its adoption in place of the several older systems. It is not surprising that there are at the present time considerable differences of opinion as to the meanings to be assigned to certain well-established terms and the names to be assigned to certain phenomena and conceptions, on the relative merits of different units and systems of units, and on the question of allocating names to these units.

Many of the terms commonly employed in electrical engineering were introduced by Faraday; in some cases he used them in the same sense as that in which they are employed to-day, but in other cases the terms are now used in an entirely different sense. It comes as a surprise, for example, to find the word "electromotor" in a letter from Faraday dated November 1834; he uses it, however, to designate a primary cell, a device for imparting motion to electricity; for, he says: "I have no doubt that if a long wire were arranged so as to discharge a single pair of plates, and the spark occurring at the breaking of contact were noted, and then another wire carrying a current in the same direction from another electromotor were placed parallel and close to but without touching the first, the spark obtained on breaking the contact at the first wire would be greater than before." As in the same letter he speaks of a single pair of plates exposing 3 sq. ft. of surface on both sides of the zinc plate, there can be no doubt as to the nature of his "electromotor."

* "Electrical Papers," vol. 2, p. 25.

Another strange word which Faraday used to designate a special form of primary cell invented by Dr. Hare of Philadelphia was "calorimotor." He says: "It is in fact a single pair of large plates, each having its power heightened by the induction of others, consequently all the positions and motions of the needles, poles, etc., are opposite to those produced by an apparatus of several plates; for if a current be supposed to exist in the connecting wire of a battery from the zinc to the copper, it will be in each connected pair of plates from the copper to the zinc, and the wire I have used is that connection between the two plates of one pair." What all this means I do not pretend to understand, but I presume from its name that the calorimotor gave such a large current that it made the wires hot.

In view of the discussion which has taken place in recent years concerning the relative merits of the spellings "starter" and "startor," "converter" and "convertor," etc., it is interesting to note that Faraday writes both "calorimotor" and "calorimoter" indiscriminately.

In their first report, issued in 1862, the British Association committee refer to "a battery or rheomotor of unit electromotive force." (Greek "rhein" = to flow.)

Another rather unexpected word occurs in a letter of 1832 from Nobili of Florence, published in the *Philosophical Magazine*, in which he speaks of "hydroelectric currents"; he says: "two (galvanometer) systems may be adopted to obtain maximum effects, the one for hydroelectric currents, the other for thermoelectric currents. The galvanometer of my thermo-multiplicator is of the latter kind and precisely that which is best in the present researches (reversing a coil in the earth's field). The reason will be evident by observing that the new currents of Faraday are entirely developed in metallic circuits, like the thermo-electricity of Dr. Seebeck, and that also like those of thermo-electricity they pass with difficulty through humid conductors." Hydroelectric currents were obviously those produced by primary cells. Nobili regarded the latter as high-voltage generators which required high-resistance

galvanometers for their effective detection—as undoubtedly they were when compared with thermo-couples and earth-inductors. That this was the recognized terminology is evident from the footnote which the editor (Poggendorff) added to Ohm's first communication in 1825, viz.: "It is to be hoped that the author will repeat his experiments with the thermo-electric chain, as the action with this is much steadier than with the hydro-electric chain and consequently lends itself to more accurate measurement."

To Faraday "ordinary" or "common" electricity was that obtained from a frictional machine; it is always so called in his "Experimental Researches." In 1833 he tabulates the five kinds of electricity as follows:—voltaic, common, magneto, thermo, and animal; the object of the paper being to show that they are all identical in nature. Volta, in a letter to a friend in England in 1792, i.e. 8 years before he invented the voltaic pile, compares *électricité animale* with *électricité commune*. One has to remember that before 1831 the only machine for generating electricity was a frictional machine, and in 1832 Faraday says: "the revolving copper plate becomes thus a new electrical machine and curious results arise on comparing it with the common machine; in the one the plate is of the best non-conducting substance; in the other it is the most perfect conductor."

Faraday could not conceive that a conducting wire, running side by side with another wire in which a large current was flowing, could be in its normal state. Since something happened in it when the neighbouring current was started and again in the reverse direction when the neighbouring current ceased, Faraday felt that the material of the conductor must be in some special state while the neighbouring current was flowing steadily. He therefore invented a term and spoke of the conductor as being in an "electrotonic state." Although he gave up the idea in after years, he occasionally showed signs of nursing it at the back of his mind. In our modern phraseology we should say that the conductor was "linked with a magnetic flux." In the 1895 British Association report we read of "total induction" in a magnetic circuit, the same quantity being also called "total flux," "total lines," "electromagnetic momentum" and "electrotonic state;" it was proposed that its practical unit (10^8 C.G.S. units) should be called a "weber." This was, I think, the last appearance of the term "electrotonic state."

Although Faraday uses the term "current," he says: "I am giving no opinion respecting the nature of the electric current now, and though I speak of the current as proceeding from the parts which are positive to those that are negative it is merely in accordance with the conventional agreement entered into by scientific men." In another place he says "that what we call the electric current may perhaps best be conceived of as an axis of power having contrary forces, exactly equal in amount in contrary directions." This reminds one of Oersted's quaint phraseology in describing his great discovery; he says: "to the effect which takes place in the conductor and in the surrounding space we shall give the name of the 'conflict of electricity' and from the preceding facts we may likewise conclude that this conflict performs circles." Dr. Wollaston in 1821 called the magnetism produced by a current "vertiginous magnetism."

In another place Faraday says: "By current I mean anything progressive, whether it be a fluid of electricity or two fluids moving in opposite directions, or merely vibrations, or speaking still more generally, progressive forces." He evidently had a very open mind on what was happening in the wire.

Although he apparently did not know the word "resistance" in 1831, he used the reciprocal conception and spoke of good and bad conductors and of the "conducting power of a circuit."

He used the term "tension" for what we should now call the "potential difference." He says: "that ordinary electricity is discharged by points with facility through air is due to its high tension." The use of the term still persists in the distinction between high-tension and low-tension currents, but is not now used in any accurate quantitative sense. It is interesting to note that in their 1863 report the British Association committee stated that they had intentionally avoided the use of this term because it had been somewhat loosely used by various writers. In 1827 Ohm referred to "electric tension," that is, difference in electric condition, and in another place to "electric tension, or difference of the bodies." He also used "electric force" and "electroscopic force," the latter because, to define the electrical states of different points, he imagined a proof-plane brought into contact and then tested on an electroscope.

Almost immediately on learning of Oersted's discovery, Ampère in October 1820 proposed an electromagnetic telegraph with a separate wire for each letter and he used the word *galvanomètre* to describe the deflected needles; he also introduced the term *astatique* and in the following year (1821) proposed the well-known astatic arrangement of two needles.

In 1834 Faraday introduced and explained many of the terms now universally employed in electro-chemistry. He had consulted Dr. Whewell of Cambridge, a philological authority, and between them they invented "electrolysis," "electrolytic," "electrodes," "anode," "cathode," "ions," "anions," "cations," and "voltameter." This last was called a "volta-electrometer" in 1834, but in Faraday's 1838 paper it appears in the shortened form.

A letter from Whewell to Faraday in 1837 contains some of the words which might have been inflicted on us. As the letter is very interesting I quote it in full:—"I am always glad to hear of the progress of your researches and never the less so because they require the fabrication of a new word or two. Such a coinage has always taken place at the great epochs of discovery; like the medals struck at the beginning of a new reign; or rather like the change of currency produced by the accession of a new sovereign; for their value and influence consists in their coming into common circulation. I am not sure that I understand the views which you are at present bringing into shape sufficiently well to suggest any such terms as you think you want. However, by way of beginning such a discussion, I would ask you whether you want abstract terms to denote the different and related conditions of the body which exercises and the body which suffers induction? For though both are

active and both passive it may still be convenient to suppose a certain ascendancy on one side. If so, would two such words as 'inductricity" and 'inducteity' answer your purpose? They are not very monstrous in their form and are sufficiently distinct. And if you want the corresponding adjectives you may call the one the 'inductric' and the other the 'inducteous' body. This last word is rather a startling one, but if such relations are to be expressed, terminations are a good artifice, as we see in chemistry, and I have no doubt if you give the world facts and laws which are better expressed with than without such solecisms, they will soon accommodate to the phrases, as they have often done to worse ones. But I am rather in the dark as to whether this is the kind of relation which you want to indicate. . . . I do not see my way any better as to the other terms, for I do not catch your objection to 'current' which appears to me to be capable of jogging on very well from 'cathode' to 'anode' or vice versa. As for positive and negative, I do not see why 'cathodic' and 'anodic' should not be used, if they will do the service you want of them."

The word "diamagnetic" was introduced by Faraday to designate a non-magnetic material, just as a "dielectric" was a non-conducting material; thus in 1845 he says: "By a 'diamagnetic' I mean a body through which lines of magnetic force are passing and which does not by their action assume the usual magnetic state of iron or lodestone." However, in 1850 he suggested to Whewell that "magnetic" should not be used as the opposite of "diamagnetic" but that "magnetic" should be general and include all the phenomena; he proposed "ferromagnetic" as the opposite of "diamagnetic," but Whewell pointed out that "ferro" was Latin and "dia" Greek, and suggested "paramagnetic" for those materials that place themselves lengthwise or parallel to the magnetic field. The word "diamagnetic" was then used to designate those bodies which are less permeable than a vacuum and which consequently set themselves transverse to the field. The fact that some bodies are diamagnetic was one of Faraday's great discoveries. I do not know whether Faraday consulted Whewell before coining the word "dielectric" in 1837. It was at this time that he introduced the term "specific inductive capacity."

Although Faraday invented the term "lines of force" and devoted much time to their elucidation, some of his statements concerning them are difficult to understand. For example, in Series 27 of the "Experimental Researches," written in 1851, he says: "There exist lines of force within the magnet of the same nature as those without. What is more, they are exactly equal in amount to those without. . . . Every line of force, therefore, at whatever distance it may be taken from the magnet, must be considered as a closed circuit, passing in some part of its course through the magnet, and having an equal amount of force in every part of its course." As the lines are equal in amount in the steel and in the air, they are lines of induction (B) and not lines of force (H); in this connection it is interesting to note that in an appreciation of Faraday in a recent number* of the *Elektrotechnische Zeitschrift*, Prof. Görges of Dresden says: "lines of force, or as we should say to-day, lines of induction." Moreover, the meaning of the concluding sentence can only be made clear by assuming that Faraday was thinking of a tube of induction and of the integral of the magnetic induction over the cross-section of the tube, since this is the only quantity that is constant in amount in every part of its course.

This example serves to show how difficult it sometimes is to discover from his writings exactly what his conceptions were; this is due partly to the fact that he was exploring entirely new fields, feeling his way and inventing terminology as he progressed, and partly to the fact that he was not mathematical and did not attempt to crystallize his ideas into formulæ.

I do not think that Faraday ever used the term "potential difference"; once in 1840 he speaks of the "electromotive force" of contact in connection with the voltaic pile, but apart from this he does not appear to have used the conception of e.m.f. Even as late as 1852 in a paper entitled "On the employment of the induced magneto-electric current as a test and measure of magnetic forces," he speaks of induced currents and thermo currents and of the application of Ohm's law, but it is very surprising that in a long paper with many numerical results and much discussion he never once mentions electromotive force. To him it was the source of the power of a voltaic cell, but in a coil or circuit the variations of the magnetic flux induced the current directly without the intermediate conception of an electromotive force.

The use of the "resistance" of a conductor rather than its reciprocal, the "conductance," seems to date from about this time; for although a paper in the *Proceedings of the Royal Society* for 1859 on the effect of pressure on electric conductibility in metallic wires contains no mention of resistance, but always refers to the conducting power of the wire, a name for the unit of resistance (but not for any unit of conductance) was suggested in a paper read at the 1861 British Association meeting. The first report of the British Association committee issued in 1862, however, generally refers to the "conducting power" of a resistance coil. Although Ohm did not use the word "resistance" in his classical paper of 1827, he used the conception, for he says that the current is inversely proportional to the sum of the equivalent lengths of the various portions of the circuit; the equivalent length being proportional to the real length divided by the product of the cross-section and the conductivity of the material. In 1831 he actually speaks of the "resistance" of the conductor ("Leitungswiderstand").

In the *Proceedings of the Royal Society* for 1859 there is a reference to "electromotive power," but in the following volume (1860) there are two papers in which Sir William Thomson uses the expression "electromotive force," which is really less accurate than the former since the magnitude to be defined is equal to the energy involved in the transfer of unit quantity of electricity, or to the power involved in the steady passage of unit current.

In a footnote to a paper in the *Proceedings of the Royal Society* for 1861, Sir William Thomson writes: "I have given the name of 'Wheatstone's Balance' to the beautiful arrangement first invented by Professor Wheat-

* *Elektrotechnische Zeitschrift*, 1931, vol. 52, p. 1105.

stone and called by himself a 'differential resistance measurer.' It is frequently called 'Wheatstone's Bridge,' especially by German writers. It is sometimes also, but most falsely, called 'Wheatstone's Parallelogram.'"

The demand for distinctive and convenient names for the various electric units came, as might be expected, from the practical men, from those who were engaged in the design and calculation of telegraph cables. They found it very inconvenient to express their measurements in so many units of resistance or units of current, and at the British Association meeting at Manchester in 1861 Charles Bright and Latimer Clark read a paper in which the following names were suggested for the principal electrical units:—"galvat" for current; "ohmad" for electromotive force; "farad" for quantity; and "volt" for resistance. It was this paper that led to the appointment of the celebrated Electrical Standards Committee of the British Association, which after 6 years of strenuous work produced the system of units now adopted internationally, although not with exactly the same names. The word "megohm" appears in an appendix to the report of 1867, from which it also appears that the "farad" was expected to do duty for both quantity and capacitance, for Fleeming Jenkin says: "This practical series of units is that which in the opinion of Mr. Latimer Clark and myself is best adapted for practical use in telegraphy. Mr. Clark calls the unit of quantity thus defined (10^{-8}) 'one Farad,' and similarly says that the unit of capacity has a capacity of 'one Farad,' it being understood that this is the capacity when charged with unit electromotive force (10^{-5})." After all, a quart is not only a measure of quantity of a liquid, but also of the capacity of the jug into which it is poured, so that it is not surprising that Latimer Clark considered one unit enough for the two purposes. In 1873 he wrote*: "The measure of quantity is the same as that of electrostatic capacity and in practice generally receives the same name, although it has been sometimes called the 'Weber;' the Weber or Farad quantity is equal to 10^{-2} absolute units. Electrical currents are defined as currents of so many farads per second. In this system, the volt electromotive force through the ohm resistance produces the unit current of one farad per second."

As an indication of the confusion which was removed largely owing to the work of the British Association committee, it may be noted that their report for the year 1864 contains a table of the relative values of 14 different units of resistance in use at the time, one of them being the "British Association unit or Ohmad." Most of them were merely the resistances of wires of arbitrarily-chosen lengths and diameters.

The following quotation from a paper by Sabine in the first volume of the *Journal*† is interesting; hardly a word of it agrees with our present nomenclature. "A condenser is an induction apparatus so arranged that when charged to a given potential its electrostatic capacity can be suddenly decreased (generally by increasing the distance between its plates) and thus the tension of its charge proportionately increased. An accumulator, on the other hand, is an induction apparatus which only collects a charge of electricity. A Leyden jar is therefore

* *Journal of the Society of Telegraph Engineers*, vol. 7, p. 86.
† *Ibid.*, 1872, vol. 1, p. 245.

an accumulator and not a condenser. . . . By inductive resistance is understood that quality of a dielectric in virtue of which it obstructs the complete polarization of its atoms, by a given difference of potential between its sides. The reciprocal of the inductive resistance of a body is what is called its 'inductive capacity.' . . . I find it convenient to express the specific inductive capacity of any insulating material in terms of the quantity of electricity which a plate one square foot coated-surface and one thousandth of an inch (or one mil) thickness is capable of containing when the inductive surfaces have a difference of potential of one volt. The unit of measurement by which the quantity of electricity thus contained is measured is called a micro-weber, and the capacity is then expressed in what are called micro-farads." Sabine evidently did not agree with Latimer Clark and Fleeming Jenkin that the same name would serve for both quantity and capacity.

The word "potential" which had been introduced originally in connection with the force of gravity, was first applied to electric fields by G. Green, and the British Association committee said in their 1863 report that "it is now coming into extensive use, but is perhaps less generally understood than any other electrical term." Kelvin had used it and defined it in a paper read before the British Association in 1852. In his 1827 paper Ohm set up ordinates proportional to the "electroscopic force" at every point of his circuit, and defined the "fall" ("Gefälle") as the difference between two ordinates separated by unit distance. He stated clearly that the current was proportional to this gradient. He actually used the word "*Abdachung*," which is equivalent to "slope."

A long appendix to the 1863 report written by Clerk Maxwell and Fleeming Jenkin did much to crystallize electrical nomenclature; they speak always of the "strength" of a current and not of its "intensity"; they define the "electric force" at a point (which Maxwell sometimes calls "electromotive intensity"), "electric induction" (which he also called "displacement") and "magnetic induction." This first committee was dissolved in 1870; in their last report, the "accumulators" of their earlier reports had become "condensers," but they had reverted entirely to the "intensity" of the current. It was two years later, however, that Sabine, as we have seen, wished to maintain a distinction between accumulators and condensers.

The committee was re-appointed in 1880, and in their first report (1881) they state that "the present usage is that a resistance of 10^9 c.g.s. units is called an 'Ohm'; an electromotive force of 10^8 c.g.s. units is called a 'Volt'; and the current produced by a 'Volt' acting through an 'Ohm' is called a 'Weber.'" It is interesting to notice that, although the name Weber had been commonly used for the unit of current for many years—so that Preece was able to report in 1873:* "I find that the practice of recording the strengths of currents in Webers has been in regular use for some years in the military school of Chatham"—the first International Congress of Electricians held in Paris in 1881 replaced it by the name of a French scientist, Ampère. Again, although Heaviside had advocated in 1885 the giving of a name to the

* *Journal of the Society of Telegraph Engineers*, vol. 7, p. 84.

practical unit of inductance and had used both " tom " and " mac," the third international congress held at Paris in 1889 decided to call it a " quadrant," but the fourth congress held at Chicago in 1893 replaced this by the name of an American scientist, Henry. More recently, on the first occasion that the international congress was held in Scandinavia, the confusion which had arisen owing to the use of the term " gauss " for the units of both H and B was removed by giving the name of a Danish scientist, Oersted, to the former unit. All of which tends to show that in the naming of units, as in other fields of international rivalry, the home team have a certain advantage.

Of all the scientists whose names have been proposed for the designation of units, the most unfortunate is Weber. The British Association committee originally proposed that the unit of quantity should be the " weber," and the unit of current, now called the " ampere," was to have been called a " weber per second ;" but the " per second " was dropped, and currents were measured in webers down to 1881 when the unit was replaced by the ampere at the Paris Congress. The 1889 Paris Congress recommended giving names to the " practical " units of flux and flux density, i.e. to 10^8 C.G.S. units, and suggested " maxwell " and " weber " respectively. The 1891 Frankfort Congress recommended the name " gauss " for the practical unit of field intensity and " weber " for the unit of flux, but again no action was taken. In their 1895 report the British Association committee recommended for tentative adoption the following terminology:—

1. " That as a unit for magnetic field a hundred million c.g.s. lines be called a ' weber.' Hence the webers ' cut ' by a closed wire circuit of n turns are equal to the quantity of electricity thereby impelled round that circuit multiplied by $1/n$ of its resistance in ohms."

2. " That the c.g.s. unit of magnetic potential or of magnetomotive force be called a ' gauss. ' Hence the number of gausses round any closed curve linked on an electric circuit is equal to 1·2566 times the number of ampere-turns in this circuit."

In this same report it is recommended that the terminations " -ance " and " -ivity " or " -ility " should be used in the manner that has since become general.

In discussing the decisions made at the Stockholm meeting in 1930, Blondel has urged that the practical unit of flux should be called the " weber " rather than the suggested " pramaxwell." As he points out, one calls 10^7 ergs a " joule " and not a " praerg."

Heaviside, writing soon after the Paris Congress, referred to the decision to apply the name " ampère " to the unit of current as a remarkable step. He objected to it as being too long and feared that it would be shortened to " amp," which he thought was not nice. His fears were well justified. " Better make it ' père,' said Heaviside, with a twinkle in his eye, " for was not Ampère the father of electrodynamics? " Writing in 1885, Heaviside advocated very short names such as " dyne " and " erg;" he not only suggested " mac," " bob," " tom " and " dick " as all being very good names for units, but pointed out with his characteristically subtle humour that if " mac " was given " max " for the plural it would have a wide national appeal. It is interesting to note that Heaviside really used " tom " as the practical unit of inductance for some years, and wrote of " millitoms " and " microtoms;" he hinted that he intended this as a compliment to Sir William Thomson. Later, in 1887, as a tribute to Maxwell, he suggested " mac " as the unit of inductance and pointed out that, if it was taken as 10^9 cm, " millimacs " would be wanted to avoid decimals. In 1893 the Chicago Congress adopted " henry " as the name for this unit, and Heaviside's " millitoms " and " millimacs " became " millihenries." It was in 1887 that Heaviside pointed out the need of practical instruments for measuring the inductance of coils " in terms of units of inductance—macs or millimacs," and suggested that such instruments should be called " inductometers." In the same year he introduced " attenuation " and " distortion " in solving transmission problems; " attenuation," he said, he found already in use by Lord Rayleigh and adopted it at once as the very thing he wanted; " distortion," on the other hand, he chose himself as preferable to " mutilation " and similar words.

The need for practical units of energy and power did not arise in connection with telegraphy, but became apparent as soon as electrical energy became an article of commerce. In the 1887 report of the British Association committee " it was resolved on the motion of Mr. Preece, seconded by Sir William Thomson, to recommend the adoption of the ' Watt ' as the unit of power. The Watt is defined to be the work done per second by the ampere passing between two points between which the difference of electrical potential is one volt." It was in this 1887 report that the " coulomb " appeared for the first time, a French convention having suggested it for international consideration as a suitable name for the ampere-second. In the 1888 report " it was resolved on the motion of Mr. Preece to adopt the name ' Therm ' for the gramme water degree Centigrade unit of heat. It was also agreed to adopt the name ' Joule ' for 10^7 c.g.s. units of work . . . hence a power of one watt is one joule per second." In 1889 the committee reported that the Paris Electrical Congress had adopted the " watt " and the " joule " and had recommended that in industrial applications the power of machines should be expressed in " kilowatts " instead of in " horse-power." This same Paris Congress also adopted Heaviside's suggested " impedance." During 1895 and 1896 much correspondence and discussion took place concerning the unit of heat; among the names suggested were " Rowland," " Meyer," " Kelvin " and " Calor." In their 1896 report the Committee suggested the " calorie," which has met with universal acceptance.

Turning again to the magnetic units we find that, although it has not shared the fate of the " weber " in being ultimately banished from the cast, the " gauss " has played so many parts that one may be excused for being somewhat uncertain as to its present rôle. In the appendix to their 1895 report, the British Association committee discuss Heaviside's suggestion that the magnetomotive force be called the " gaussage " and that its C.G.S. unit be one " gauss "; they speak of the difference of magnetic potential between two points as the fall of " gausses " or the " gauss-fall " from A to B. " Intensity of magnetic force, or H, will be naturally

expressed as gauss-fall per centimetre, or the gauss-gradient."

At the conclusion of the 1900 Paris Congress great confusion was caused by some of the delegates going away thinking that they had given the name gauss to the unit of magnetic induction (B), while others were under the impression that it had been given to the magnetic force (H). The confusion was really due to the failure to recognize the essential difference between H and B, and the necessity for giving names to each. This point had been strongly emphasized in the 1895 British Association report, which said: "That the essentially different quantities commonly called H and B should be carefully kept distinct, although their measures in air have been conventionally so arranged as to be numerically equal. H should not (strictly speaking) be expressed as so many lines per square centimetre; that mode of expression should be reserved for induction density B. H is the cause and should be thought of as the slope of magnetic potential; B is the effect. In a medium of so-called unit permeability the two quantities are numerically equal, but they should not be confounded, any more than the slope of electric potential, or electric intensity, should be thought of as identical with current-density even in a medium of unit conductivity. Now, as must often have been pointed out, the equation $B = H + 4\pi I$ is a barbarous one, involving as it does quantities of different dimensions. . . ."

Dr. Johnstone Stoney, who was a member of the committee, was in favour of interchanging the names "gauss" and "weber"—an ominous sign. Long before this, however, in 1882, Heaviside—in discussing a disagreement between Clausius and Maxwell as to the dimensions of a magnet pole—said: "the error appears to lie in the neglect of the distinction between magnetic force and magnetic induction."

The name "permeability" for the relation between the magnetic induction (B) and the magnetizing force (H) was originally suggested by Kelvin in 1872; he pointed out that it was analogous to the relation between heat flow and temperature gradient and between liquid flow and pressure gradient in a porous medium. Faraday had called it "the conducting power of a magnetic medium for lines of force." In 1886, however, Heaviside suggested* that "permeability" should be abolished and replaced by "inductivity," which would indicate its connection with magnetic induction and self and mutual inductance.

The muddle which ensued from the misunderstanding at the Paris Congress was cleared up by the International Electrotechnical Commission at Oslo in July 1930. It was decided that the C.G.S. unit of flux should remain a "maxwell," that the unit of flux density or induction (B) should be a "gauss," that the unit of magnetomotive force should be a "gilbert," and that the unit of magnetizing force (H) should be an "oersted"—a fitting recognition of the scientist who first discovered a connection between electricity and magnetism. As Prof. Kennelly† has said: "By far the most important result of the new I.E.C. resolutions is that, if followed, the indefiniteness and ambiguity which have often characterized the literature of the magnetic circuit, on questions of H and B, can be eliminated. The term gauss, for instance, can only be used for flux density B."

In 1926 the British Engineering Standards Association published a "Glossary of Terms used in Electrical Engineering,"* but unfortunately the sections dealing with the fundamental terms of electrical technology were very confused and in no way representative of generally-accepted usage. Cause and effect in magnetic and electric phenomena were so mixed up together that many of the definitions were unintelligible. If the Zoological Society invited a person to write a guide to the Zoo, not knowing that he had philosophic doubts as to the objective existence of, say, the rhinoceros and hippopotamus, the person would have three alternatives, apart from that of declining the task. He might keep his philosophic doubts to himself and describe the two animals from the point of view of his less enlightened brethren, or he might omit their names and all reference to them, or, finally, he might bestow their names upon some other animals, say, a variety of polar bear. The authors of the Glossary were in a somewhat analogous position. Most authorities assume that an electric force E acting on a dielectric produces an electric displacement D, and that a magnetizing or magnetic force H produces a magnetic induction B. The authors of the Glossary, having doubts about the existence of the electric displacement and of the magnetic induction, merged them into the forces that produce them and were left with these two widely-used terms on their hands. They adopted the second alternative in the case of displacement and omitted it entirely, but in the case of magnetic induction they adopted the third method, and bestowed the name on another quantity altogether, namely the total magnetic flux. This lack of discrimination between cause and effect prevails throughout these sections of the Glossary and leads to general confusion. For example, having defined electrostatic flux as the number of unit electrostatic tubes of force, so that one cannot distinguish between force and flux, they then define dielectric hysteresis as the lagging of the electrostatic flux behind the electric force producing it. Excitation is defined as the magnetizing force (symbol H) producing the flux in an electromagnet; coercive force is defined as the magnetomotive force required to annul the residual magnetism of a substance, and so on. As I have said on a previous occasion, such a production should not have been issued with the authority of the British Engineering Standards Association.

As an example of the confusion existing at the present time in the nomenclature of magnetic quantities, we might refer to the *Journal of Scientific Instruments* for April 1931, where a curve is stated to show the values of B for values of H from 0 to 0·5 gauss. The curve itself gives H in gilberts, the maximum being 0·08 gilbert, and B in gausses up to 5 000. What relation 0·5 gauss may bear to 0·08 gilbert, or what relation either of them may bear to the value of H in oersteds, the unit recommended by the International Electrotechnical Commission in 1930, is left to the reader's imagination. Another example occurs in a pamphlet on the physical properties of nickel-iron issued in July 1931 by the Mond Nickel Co.

* *Electrician*, 1886, vol. 16, p. 271.

† *Transactions of the American I.E.E.*, 1931, vol. 50, p. 737.

* B.S.S. No. 205—1926.

Fig. 1 in this pamphlet gives the μ-H curves of several nickel alloys and Fig. 2 gives those of mumetal and commercial silicon iron for comparison, but in Fig. 1 the magnetizing force is given in gilberts per cm, whereas in Fig. 2 it is given in gausses. How is the average reader of a pamphlet on nickel to know that these are one and the same thing, and that they are both what we used to call "C.G.S. units," and what the Oslo Conference decided must in future be called "oersteds?" It is quite possible, moreover, that the next magnetization curve he comes across will be plotted to none of these but to ampere-turns per cm.

In 1886 Heaviside said: "if we pass to electric displacement, the analogue of magnetic induction (noting by the way that it had better not be called the 'electric induction,' on account of our already appropriating the word 'induction,' but be called 'displacement'), the existing terminology is extremely unsatisfactory." He then suggested altering the definition of specific inductive capacity, or, as he preferred to call it, "specific capacity," so that it would be the capacitance of a unit cube; this would entail hiding the 4π in the specific capacity, so that it would not intrude itself in the subsequent calculations of capacitance from the dimensions of the condenser.

He expressed his dislike of the adjectives "capacious" and "incapacious" and of the inverse noun "incapacity:" he also thought the word "capacity" rather objectionable as likely to give beginners entirely erroneous notions. His wishes have been largely met, for "capacitance" has largely replaced "capacity," and the adjective generally used is "capacitive"—although one often sees the strange word "capacitative." Fortunately the reciprocal has not been introduced, and we have not been threatened with "daraf" as the name of a unit.

Heaviside suggested "permittance" instead of "capacity," and "elastance" as its reciprocal. He drew up the following table:—

Flux	Force/Flux	Flux/Force	Force
Conduction current	Resistance Resistivity	Conductance Conductivity	Electric
Induction	Reluctance Reluctivity	Inductance Inductivity	Magnetic
Displacement	Elastance Elastivity	Permittance Permittivity	Electric

He invented the words "elastance" and "elastivity" to avoid having to say "electric elasticity," or run the danger of confusion with other elasticities. "Reluctance" and "reluctivity" were not in the original table; he invented them later so as to avoid the use of "magnetic resistance." It was in this same paper that he suggested the word "impedance" for the ratio of the amplitude of the impressed electromotive force to that of the current. He also suggested that a coil used for impeding might be called an "impeder."

In 1904 the British Association committee considered and reported on two suggestions put forward by Prof. Kennelly. The first was that the absolute units should have the same names as the corresponding practical units but with the prefix "abs" or "abstat" depending on whether the electromagnetic or the electrostatic absolute system was adopted. The committee disagreed with any prefixes which did not bear definite numerical signification. Prof. Kennelly has, however, consistently adopted this plan himself in a slightly simplified form, and employs "abohms," "statfarads," etc. His second suggestion was the adoption of a systematic nomenclature for the magnetic units. Now although personal names had been given to the practical electrical units and not to the C.G.S. units, the committee, for reasons not stated, were in favour of basing any nomenclature on the C.G.S. magnetic units, but were of the opinion that a system of nomenclature was not called for. Moreover, the committee showed their disapproval of Prof. Kennelly's proposals by consistently mis-spelling his name. The Paris Congress had already in 1900 recommended the name "maxwell" for the C.G.S. unit of magnetic flux, and the British Association committee had in the same year adopted it, and had also adopted the gauss for the C.G.S. unit of magnetic field.

Prof. Kennelly has now carried his system of prefixes a step further, for he calls the practical magnetic units by the same name as the corresponding C.G.S. units but adds the prefix "pra" as an abbreviation of "practical." These units are still in an unsettled state, and although one can say with certainty that a "pramaxwell" is a magnetic flux of 10^8 C.G.S. units or that a "praline" is 10^8 lines, there is no such certainty about the meaning of a "praoersted" or of a "pragilbert." The obvious practical unit of electromotive force is the ampere-turn, or simply the ampere, without any $4\pi/10$, and little is gained by calling it a "pragilbert." The giving of names to all the C.G.S. magnetic units appears to have introduced much unnecessary complication.

Some dissatisfaction has been expressed over the mutilation of the names of great scientists in making names for units. "Farad" and "volt" are two examples, but the most undignified and ugly procedure is the reversal of a name to designate a reciprocal. The unit of conductance is a case in point, and in suggesting the name of Siemens for this unit the German National Committee protested against the use of the word "mho." In 1896 a leading French scientist suggested that the unit of permeance should be called the "arago"; he has lately suggested that the unit of its reciprocal, reluctance, should be given the horrible name "ogara." More recently an American has published a table in which the unit of reluctance is called a "yrneh."

A practice has grown up in Germany in recent years to refer to a frequency of 50 cycles per second as a frequency of 50 "hertz," but, although it has been brought before the International Electrotechnical Commission, the "hertz" has not been officially recommended as the unit of frequency. One of the most recent additions to electrical nomenclature is the "bel," after Graham Bell, as the unit of attenuation or amplification of a signal in passing through any line or apparatus. The name of "neper," after the inventor of logarithms, has also

been used for the same purpose. Either is preferable to "transmission units," which is invariably shortened to "T.U."

There are many units to which I have not been able to refer in the time available, and no reference has been made to illumination and other subjects closely allied to electrical engineering, but I have attempted to give a general outline of the evolution during the last hundred years of the nomenclature of the main fundamental conceptions of electrical engineering.